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The Status of Redfish in Div. 3O

by

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Abstract

Catches have ranged from 5,000 t to 35,000 t since 1959 and have averaged 13,000 t from 1989-1993. The 1994 catch of about 5,100 t represents an 11,000 t reduction from 1993. The TAC was reduced from 14,000 t in 1993 to 10,000 t for 1994 and 1995. Foreign fleets, which predominantly fish outside the 200 mile limit, account for most of catch. Canada fishes inside the 200 mile limit and less than 200 t have been taken each year since 1982, but have increased landings to over 700 t in recent years. Standardized commercial catch rate shows declining trend since 1979 but is probably more indicative of a decline in the proportion of the stock outside the 200 mile limit where most of the effort is located. Spring and autumn surveys since 1991 show different trends and are difficult to interpret. There is considerable uncertainty regarding the current size of the stock and the level of fishing mortality being applied. Based on recent research vessel data the stock appears to be mostly comprised of young immature fish, although significant amounts of larger fish have been found during research surveys in the past in the deeper, hard-to-fish areas of the Division.

Résumé

Les prises se sont échelonnées entre 5 000 et 35 000 tonnes depuis 1959 et se sont situées en moyenne à 13 000 t de 1989 à 1993. Les prises de 1994 (environ 5 100 t) représentent une réduction de 11 000 t par rapport à 1993. Le TAC est passé de 14 000 t en 1993 à 10 000 t en 1994 et 1995. Les prises sont essentiellement capturées par les flottes étrangères, qui pêchent hors de la limite des 200 milles. Les bateaux canadiens, qui eux pêchent à l'intérieur de la zone de 200 milles, ont capturé annuellement moins de 200 t depuis 1982, mais leurs débarquements sont passés à plus de 700 t ces dernières années. Le taux de prises commerciales normalisé révèle une tendance à la baisse depuis 1979; toutefois, cette tendance est peut être davantage révélatrice d'une baisse de la proportion du stock se trouvant hors de la limite des 200 milles, où la plupart de l'effort est concentré. Les relevés de recherche de printemps et d'automne réalisés depuis 1991 révèlent des tendances différentes et sont difficiles à interpréter. L'incertitude quant à l'effectif du stock et au degré de mortalité par pêche est considérable. D'après des données recueillies récemment par navire de recherche, le stock semble être surtout composé de jeunes poissons immatures, quoique, durant les relevés de recherche antérieurs, on ait dénombré d'importantes quantités de plus gros poissons dans les eaux profondes de la division, où il est difficile de pêcher.

Description of management regulations and the fishery

Management regulations

A TAC of 16,000 t was first implemented on this stock in 1974. The TAC was raised in 1978 to 20,000 t on the assumption that the stock was healthy and generally remained at that level through to 1987. The TAC for 1988 was reduced to 14,000 t and remained unchanged until 1994 when it was reduced to 10,000 t. The 1995 TAC remained at 10,000 t. In addition to quota regulation, a small fish protocol at 22 cm was implemented inside the 200 mile limit for this stock in 1995.

Nominal Catches

Since 1959, nominal catches have been in the range of 5,000 t to 35,000 t (Fig. 1). Up to 1986 catches averaged 13,000 t, increased to 27,000 t in 1987 with a further increase to 35,000 t in 1988 (Table 1, Fig. 1). Catches declined to 13,000 t in 1989, and were about this amount annually through to 1993. The 1994 catch of about 5,100 t represents an 11,000 t reduction from 1993. This is mostly accounted for by a reduced foreign allocation in 1994. The increased catches in 1987 and 1988 were due to increased activity outside the 200 mile Exclusive Economic Zone (EEZ) by countries who were contracting parties of NAFO (primarily Panama and South Korea). Canadian surveillance estimates of catch are included in catch statistics since 1983 (Table 1). Details of this is given in Shelton and Atkinson (1994).

Russia predominated in this fishery up until 1993 and generally took its share (about 50%) of the total non-Canadian allocation, which accounted for about 2/3 of the TAC. Russia had a very limited fishery in 1994 and Cuba did not participate at all (Table 1). Portugal, which began fishing in the area in 1992 took 2,900 t in 1994, a reduction of 2,000 t from their 1993 catch. Canada, which landed less than 200 t from 1983-1991, took 1,600 t in 1994 due to improved markets related to lobster bait. For 1995, the reported Canadian catch to September 20 is only about 120 t. The reduction is related to the implementation of a small fish protocol. The non-Canadian catch as reported to NAFO up to the middle of September is only 673 t with about 66% of this reported by Russia.

The fishery has occurred primarily in the second and third quarters of the year since 1983 (Table 2). The prominent means of capture from the mid-1970s to the early 1980s was the bottom otter trawl (Table 3), but since 1984 there has been an increase in the use of the midwater trawl.

Available Data

Commercial catch rates

Catch and effort data for 1959 to 1992 were extracted from ICNAF/NAFO Statistical Bulletins and were combined with provisional 1993 NAFO data and 1993-1994 Atlantic region data compiled by various DFO regional statistics branches. Initially selected from this database were observations where redfish comprised more than 50% of the total catch and were therefore considered to be redfish directed.

These data were analyzed with a multiplicative model (Gavaris 1980) to derive a standardized catch rate series. The effects included in the model were a combination country-gear-tonnage class category type (CGT), month, and a category type representing the amount of bycatch associated with each observation. For this effect five groups were arbitrarily established : (>50% <=60%), (>60% <=70%), (>70% <=80%), (>80% <=90%) and (>90%) where each group corresponds to the percentage of redfish relative to the total catch associated with each observation. In the usual manner, catch or effort data of less than 10 units were eliminated prior to analysis in addition to any categories with less than five samples except in the year category type. For all analyses an unweighted regression was run because of unknown percentages of prorating prior to 1984.

In previous catch rate analyses of this stock there were questions raised as to whether the standardized catch rate series was representative over the entire division. It was reasoned the declining trend apparent from 1979 to 1992 may be more indicative of a decline in the proportion of the stock outside the 200 mile limit where most of the effort is concentrated (Shelton and Atkinson, 1994). To investigate this, catch rate series were developed separately for different countries: for Canada which has fished inside the EEZ, for Russia and Cuba which have fished both inside and outside the EEZ, and, for those countries which have fished outside the EEZ (Japan, Poland, Portugal and South Korea). A preliminary analysis of 1994 data suggested a large increase in the 1994 catch rate. As this was based only on preliminary Canadian data, it was decided to exclude this year from the analysis.

For the standardization including all countries, the model utilizing effort measured in hours fished explained 63% of the variability in the catch rates (Table 4a). All category types are significant. Even though the year category type is significant, only the last three years (1991-1993) have significantly different coefficients from the reference. Estimated coefficients from the regression show catch rates are generally highest in the June-August period. Examination of residual plots did not indicate that the model was inappropriate. The standardized catch rate index (Table 4b, Fig. 2a) shows much interannual variability from 1959 to 1978. In 1979 there was a dramatic increase in the rate followed by a general decline to the lowest rate in the series in 1993. Large fluctuations from year to year, primarily in the pre-1979 period are not considered reflective of the dynamics of such a long lived species as redfish.

The analysis of Canadian catch rates (Table 5a) resulted in a significant overall regression explaining 68% of the variability in the data, however, the month category type was not significant ($P > .05$). The catch rate index (Table 5b, Fig. 2b) shows much interannual variability but indicates a different trend over the period since the mid-1970s compared with the trend for all countries combined.

The third analysis was conducted on catch rates for countries who have fished both inside and outside the EEZ (Russia and Cuba). The regression was significant ($P < .05$) and explained 65% of the variability in catch rates (Table 6a). The catch rate index (Table 6b, Fig. 2c) again shows much interannual variability prior to 1977. The index shows a steady increase from 1977 to 1982 and a general decline to 1993 similar to the all countries combined index.

The final analysis was conducted on catch rates for countries which have only fished outside the EEZ. The overall regression was significant ($P < .05$) and explained 50% of the

variability in catch rates (Table 7a), however, only the factor representing the percentage of redfish in the catch was significant ($P < .001$). Fishing was sporadic by these countries prior to 1984. The catch rate index (Table 7b, Fig. 2d) shows a steady decline from 1984 to 1993.

The analysis of catch rates using Canadian data only suggests a different trend over the period since the 1970s compared to non-Canadian fleets operating only outside the EEZ. Canada has not accounted for a major portion of the reported catches from Division 3O and has only fished within the 200 mile EEZ. Therefore, the trend in overall catch rates is probably more indicative of a decline in the proportion of the stock outside the EEZ where most of the effort occurs. Further investigations of these data are necessary.

Catch at Length

Length distributions sampled from the 1994 fishery (Fig. 3) by Canadian port samplers and Portuguese observers aboard Portuguese vessels (Avila de Melo, 1995) suggest the catch was dominated by lengths between 22 cm and 30 cm. Additional information recorded with the length frequencies indicate fishing occurred between 253-851 m. Modal lengths between 27 and 30 cm were common among the frequencies.

Research vessel surveys

Stratified random groundfish surveys have been conducted in the spring and autumn in Division 3O since 1991, with coverage to depths down to 730 m. In addition, a summer survey was conducted in 1993. The spring survey biomass index (Table 8, Fig. 4) increased steadily from about 7,000 t in 1992 to 84,000 t in 1995, although 47,000 t of this estimate was accounted for by two large catches of about 5,000 kg each in a relatively small stratum. The 1993 summer survey index, at 52,000 t, was similar to the level estimated from the 1993 spring survey (42,000 t). The autumn survey biomass index has ranged between 16,000 t and 28,000 t from 1991 to 1994, although the 1992 autumn survey only covered depths down to 370 m (200 fathoms).

These results are difficult to interpret. Stratum by stratum estimates indicate that the increases during the spring surveys occurred over a great deal of the area, although the biomass estimates for strata outside 200 miles were relatively low compared to those inside. The distribution of the catches (Fig. 5) shows the increase in spring density from 1993 to 1995 relative to the 1991-1992 period occurred over a large area. The differences between the spring and fall surveys may be related to changes in availability within the Division at different times of the year.

Size composition and numbers at age (Fig. 6) indicate a bimodal distribution in the 1991 spring survey with modes at 11 cm and 20 cm corresponding to the 1988 and 1984 year classes respectively. These modes progress in the surveys up to the 1992 fall survey when the modes were at 17 cm and 22 cm. The length distributions estimated in each of the three 1993 surveys showed mostly identical modes compared to the 1992 fall survey. The modes in the 1994 survey were at 18-19 cm and 23 cm and the 1995 spring survey showed a single mode at 19 cm. It is unknown how this relatively slow growth after the fall of 1992 relates to the increases in the biomass index over the same period, although migration to and from the area at certain sizes is a possibility that should be explored. It is also apparent that a low proportion of the size distribution has been accounted for by fish greater than 25 cm in most of the surveys since 1991.

By comparison, length distributions from sampling of the 1994 fishery generally showed a relatively high proportion of fish greater than 25 cm, suggesting that there is a component of the population in the area which may be undersampled during the surveys.

ESTIMATION OF STOCK PARAMETERS

Total mortality

Catch-at-age data from the commercial fisheries are available for 1987 to 1990 (Power MS 1991). In order to carry out catch curve analysis of these data, the estimates were divided by the standardized effort from the multiplicative analysis of catch and effort data to derive estimates of catch rate-at-age. The data were then input into a multiplicative model (Shepherd and Nicholson 1991, Sinclair 1992) which included both age and year class effects. The model used was:

$$\ln (CPUE_{ij}) = \alpha + Ai + YCj + \varepsilon$$

where $CPUE_{ij}$ is the catch rate at age i and year-class j, A and YC are the overall age and year-class effects respectively, α is the intercept and ε is the error term.

Previous analyses (e.g. Sinclair 1992) used the adjusted least squares (LS) means from the analysis to construct a catch curve from which total mortality (Z) was then estimated by linear regression. For the Division 3O data, the LS means were plotted, an appropriate range of ages selected (9 to 25) based on visual examination, and another multiplicative analysis carried out using only the selected ages to determine total mortality. The form of the model was:

$$\ln (CPUE_{ij}) = \alpha + \beta Ai + YCj + \varepsilon$$

where $CPUE_{ij}$ is the catch rate at age i (9 to 25) and year-class j, YC is the overall year-class effect, β is the slope, α is the intercept and ε is the error term. Total mortality (Z) is equal to β.

The results (Table 9) indicate total mortality (z) of about 0.26. Assuming natural mortality (M) is 0.10, then fishing mortality (F) was about 0.16 compared to $F_{0.1}$ of 0.13. As there are 17 ages included in the analysis, this estimate represents the average of a 17 year period (1974 to 1990). During this period catches averaged about 15,000 t.

PROGNOSIS

It is not possible to estimate the current size of this stock. It is not possible to determine current fishing mortality, or the possible fishing mortality generated by catching the TAC of 10,000 t in 1995. There are indications that fishing mortality was somewhat above $F_{0.1}$ during the 15 years prior to the 1990s when catches averaged about 15,000 t.

Recently, more small redfish appear to be available in Division 3O based on research vessel surveys conducted during the 1990s. However, it is unclear whether redfish in this area are resident or migrants from another area. Based on the research vessel data, the stock appears to be mostly comprised of young immature fish, although significant amounts of larger fish have been found during research surveys in the past in the deeper, hard-to-fish areas of the Division and also dominated the 1994 commercial catch. The length at which half the females are sexually mature

(L_{50}) is about 29 cm (11 inches). Given that generally the shallower the depth fished the smaller the size composition, caution is warranted because a greater proportion of immature females may be captured if fishing is concentrated in shallower water (less than 375 m (205 fathoms)).

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Table 1a. Nominal catches (t) of redfish in Division 3Ø by country and year.

Country	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992[a]	1993[a]	1994[a]
Canada (M)	417	47	4	29	48	5	24	5	18	27	4	27	21	779
Canada (N)	2,160	444	3	138	56	136	159	176	9	128	24	1,192	677	845
France	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Japan	-	496	1	1,258	661	1,162	1,074	1,606	1,724	1,406	226	125	159	-
Portugal	-	5	-	-	-	-	-	22	12	83	3	1,468	4,781	2,916
Spain	-	-	-	25	630	45	26	4	-	4	-	-	-	26
Russia	8,659	8,717	5,670	7,262	5,905	6,099	7,152	4,921	4,517	3,811	4,427	5,845	6,887	60
Cuba	1,368	1,651	1,460	1,316	806	3,006	2,859	2,753	2,138	2,750	2,748	2,776	665	-
USA	-	-	-	-	104	2	-	-	-	-	-	-	-	-
Korea(S)	-	-	-	-	-	-	1,726	1,805	2,638	833	129	1,935	17	-
EEC	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other[b]	-	-	200	6,950	4,650	600	14,150	23,500	2,200	5,200	900	1,900	2,500	500
Total	12,604	11,360	7,340	16,978	12,860	11,055	27,170	34,792	13,256	14,242	8,461	15,268	15,707	5,126
TAC	20,000	20,000	20,000	20,000	20,000	20,000	20,000	14,000	14,000	14,000	14,000	14,000	14,000	10,000

[a]Provisional.

[b]Estimates of non-reported catch (by Canadian Surveillance)

Table 2. Nominal reported catches (t) of redfish in Division 3Ø by month and year (not including surveillance estimates).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1981	991	3,735	1,444	1,601	621	1,467	773	584	510	873	5	-	12,604
1982	-	1	1,121	1,258	545	652	4,555	2,245	661	233	89	-	11,360
1983	254	355	2,904	1,227	71	156	576	938	319	1	73	266	7,140
1984	219	155	2	32	85	257	446	3,210	2,799	1,882	435	506	10,028
1985	1,522	-	453	239	118	252	227	1,710	1,486	350	35	1,817	8,210[b]
1986	707	-	427	593	69	710	3,491	3,712	58	1	319	368	10,455
1987	102	40	1,052	37	1,010	757	2,001	4,142	429	344	1,326	1,780	13,020
1988	15	1	493	684	915	1	1,755	3,922	1,286	1,057	915	248	11,292
1989	228	585	224	6	674	1,411	1,143	3,311	2,737	666	51	20	11,056
1990	108	23	257	26	1,220	2,474	1,534	1,571	1,002	686	28	113	9,042
1991	17	47	96	1	713	2,054	2,346	418	830	338	0	1	7,561
1992[a]	0	57	14	10	635	3,262	2,520	1,808	896	1,261	797	2,108	13,368

[a]Provisional.

Table 3. Nominal reported catches by gear type for redfish in NAFO Div. 3Ø (not including surveillance estimates).

	Div. 3Ø				
Year	Bottom trawl	MW trawl	Gillnets	Misc.	Total
1981	9,991	2,613	-	-	12,604
1982	9,394	1,966	-	-	11,360
1983	5,217	1,923	-	-	7,140
1984	7,451	2,577	-	-	10,028
1985	4,431	3,778	-	1	8,210
1986	5,231	5,224	-	-	10,455
1987	8,601	4,419	-	-	13,020
1988	6,692	4,596	-	4	11,292
1989	7,026	4,030	-	-	11,056
1990	5,501	3,537	-	4	9,042
1991	4,625	2,936	-	-	7,561
1992[a]	10,046	3,292	1	29	13,368

[a]Provisional.

Table 4a. ANOVA results and regression coefficients from a multiplicative model utilized to derive a standardized catch rate series for Redfish in Div. 3O. All countries were utilized in the analysis. Effort is measured in hours fished (1993 based on preliminary data).

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.795

MULTIPLE R SQUARED..... 0.632

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	2.855E1	2.855E1	
REGRESSION	70	1.726E1	2.466E0	11.900
Country,Gear*TC	22	6.792E1	3.088E0	14.910
Month	11	1.042E1	9.473E0	4.573
Bycatch PCT	4	1.843E1	4.607E0	22.245
Year	33	1.847E1	5.598E0	2.703
RESIDUALS	486	1.006E2	2.071E0	
TOTAL	557	3.029E2		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
Country,Gear*TC	20127	INTERCEPT	0.321	0.154	557
Month	8				
Bycatch PCT	35				
Year	59				
(1)	2114	1	-0.944	0.138	20
	2125	2	-0.795	0.127	19
	2114	3	-1.488	0.582	7
	2125	4	-1.090	0.096	35
	2135	5	-0.287	0.210	6
	4127	6	-0.547	0.121	19
	4157	7	-0.025	0.102	32
	9114	8	-1.621	0.221	6
	14124	9	-0.175	0.177	8
	14125	10	-0.449	0.217	5
	14126	11	-0.408	0.125	18
	14127	12	-0.248	0.103	30
	19127	13	-0.635	0.220	6
	17126	14	-0.456	0.187	8
	20114	15	-1.482	0.151	14
	20157	16	-0.101	0.078	55
	25125	17	-0.222	0.122	17
	25127	18	-0.038	0.112	29
	27125	19	-0.693	0.150	11
	34126	20	-0.053	0.295	3
	34127	21	-0.274	0.294	3
	34157	22	-0.202	0.349	2
(2)	1	23	-0.282	0.125	19
	2	24	-0.328	0.121	22
	3	25	-0.154	0.095	40
	4	26	-0.585	0.104	30
	5	27	-0.051	0.092	43
	6	28	-0.021	0.087	52
	7	29	-0.028	0.075	81
	9	30	-0.064	0.079	68
	10	31	-0.136	0.086	52
	11	32	-0.309	0.095	39
	12	33	-0.288	0.098	37
(3)	55	34	-0.694	0.095	35
	65	35	-0.466	0.085	45
	75	36	-0.360	0.078	47
	85	37	-0.349	0.056	105
(4)	60	38	0.154	0.294	3
	61	39	0.237	0.235	6
	62	40	0.055	0.196	11
	63	41	0.148	0.190	13
	64	42	0.284	0.237	6
	65	43	-0.046	0.255	5
	66	44	0.184	0.366	2
	67	45	0.372	0.218	7
	69	46	-0.207	0.210	9
	70	47	-0.066	0.203	10
	71	48	0.175	0.188	14
	72	49	-0.141	0.177	17
	73	50	0.134	0.209	9
	74	51	-0.267	0.209	9
	75	52	-0.340	0.231	6
	76	53	0.111	0.167	23
	77	54	0.001	0.169	20
	78	55	-0.152	0.162	24
	79	56	0.318	0.160	32
	80	57	0.191	0.164	26
	81	58	0.256	0.166	23
	82	59	0.299	0.166	25
	83	60	0.201	0.179	17
	84	61	0.114	0.167	25
	85	62	0.107	0.174	21
	86	63	0.022	0.182	18
	87	64	0.090	0.164	33
	88	65	0.069	0.166	30
	89	66	-0.192	0.172	26
	90	67	-0.133	0.172	24
	91	68	-0.457	0.204	10
	92	69	-0.369	0.165	31
	93	70	-0.542	0.240	8

Table 4b. Standardized catch rate series for Div. 3O redfish from a multiplicative model utilizing hours fished as a measure of effort. All countries were utilized in the analysis.

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1959	0.9209	0.0238	2.753	0.422	9268	3366
1960	1.1051	0.0792	3.220	0.889	5030	1562
1961	1.1578	0.0511	3.442	0.769	11394	3311
1962	0.9793	0.0305	2.909	0.505	7557	2598
1963	1.0692	0.0278	3.187	0.528	11807	3705
1964	1.2051	0.0480	3.614	0.783	20161	5578
1965	0.8745	0.0576	2.584	0.612	19791	7659
1966	1.1053	0.1228	3.151	1.072	15305	4858
1967	1.2933	0.0380	3.967	0.767	19037	4799
1969	0.7138	0.0323	2.229	0.398	15911	7139
1970	0.8553	0.0297	2.571	0.440	13221	5143
1971	1.0963	0.0235	3.282	0.501	19802	6034
1972	0.7795	0.0191	2.396	0.330	16117	6728
1973	1.0549	0.0285	3.140	0.527	8797	2801
1974	0.6540	0.0300	2.102	0.362	13124	6245
1975	0.5807	0.0428	1.941	0.398	15110	7786
1976	1.0213	0.0144	3.058	0.367	15348	5019
1977	0.9425	0.0158	2.825	0.354	10851	3842
1978	0.7684	0.0151	2.374	0.291	6860	2890
1979	1.2394	0.0135	3.805	0.441	17737	4661
1980	1.1114	0.0131	3.349	0.382	17306	5168
1981	1.1769	0.0144	3.573	0.428	12604	3527
1982	1.2203	0.0128	3.734	0.422	11360	3042
1983	1.1218	0.0174	3.376	0.443	7340	2174
1984	1.0348	0.0136	3.101	0.360	16978	5475
1985	1.0275	0.0162	3.075	0.390	12860	4183
1986	0.9428	0.0181	2.822	0.378	11055	3917
1987	1.0105	0.0119	3.029	0.329	27170	8969
1988	0.9900	0.0121	2.968	0.326	34792	11724
1989	0.7293	0.0143	2.284	0.273	13256	5804
1990	0.7878	0.0144	2.421	0.290	14242	5882
1991	0.4636	0.0248	1.742	0.273	8461	4857
1992	0.5319	0.0198	1.870	0.262	15268	8167
1993	0.3791	0.0460	1.584	0.336	15707	9917

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.161

Table 5a. ANOVA results and regression coefficients from a multiplicative model utilized to derive a standardized catch rate series for Redfish in Div. 3O. Only Canadian data were utilized in the analysis. Effort is measured in hours fished (1993-94 based on preliminary data).

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.822

MULTIPLE R SQUARED..... 0.675

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	5.810E0	5.810E0	
REGRESSION	49	3.918E1	7.995E-1	4.952
Country Gear TC	5	5.145E0	1.029E0	6.387
Month	9	2.288E0	2.542E-1	1.575
Bycatch PCT	4	2.503E0	6.256E-1	3.877
Year	31	1.557E1	5.023E-1	3.113
RESIDUALS	117	1.885E1	1.611E-1	
TOTAL	167	6.384E1		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
Country Gear TC	3125	INTERCEPT	0.210	0.221	167
Month					
Bycatch PCT	95				
	99				
	2115	1	-0.047	0.166	20
	2125	2	0.205	0.149	19
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	3155	4	1.074	0.204	9
	3199	5	0.304	0.159	11
2	3	5	-0.376	0.225	5
	4	7	-0.166	0.239	5
	5	8	-0.205	0.145	15
	6	9	-0.023	0.139	17
	8	10	0.113	0.123	24
	9	11	-0.124	0.119	24
	10	12	-0.291	0.128	25
	11	13	-0.265	0.165	14
	12	14	-0.287	0.220	5
3	55	15	-0.501	0.177	11
	65	16	-0.492	0.170	11
	75	17	-0.083	0.166	9
	85	18	-0.035	0.108	32
4	51	19	-0.165	0.365	2
	57	20	0.012	0.244	6
	61	21	-0.441	0.221	7
	62	22	-0.445	0.217	8
	64	23	-0.329	0.285	4
	65	24	-0.017	0.337	2
	66	25	-0.662	0.442	1
5	67	26	0.000	0.227	7
	69	27	-0.837	0.353	2
	70	28	-0.195	0.302	3
	71	29	-0.020	0.443	1
	72	30	-0.434	0.248	8
	73	31	-0.307	0.450	1
	74	32	-0.790	0.298	3
	75	33	-0.845	0.262	4
	76	34	-0.428	0.213	12
	77	35	-0.501	0.204	15
	78	36	-0.445	0.197	13
	79	37	-0.110	0.209	16
	80	38	-0.349	0.223	10
	81	39	-0.255	0.216	10
	82	40	-0.437	0.304	3
	84	41	-0.182	0.332	2
	85	42	0.267	0.311	3
	86	43	-0.202	0.458	1
	87	44	0.040	0.342	2
	88	45	-0.356	0.445	1
	90	46	-0.121	0.457	1
	92	47	-1.026	0.279	6
	93	48	-1.015	0.311	3
	94	49	-0.369	0.344	4

Table 5b. Standardized catch rate series for Div. 3O redfish from a multiplicative model utilizing hours fished as a measure of effort. Only Canadian data were utilized in the analysis.

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1959	0.2103	0.0490	1.306	0.287	59	45
1960	0.0526	0.1042	1.085	0.343	60	55
1961	0.2221	0.0648	1.311	0.330	61	47
1962	-0.1996	0.0427	0.869	0.179	62	71
1963	-0.2361	0.0427	0.838	0.172	63	75
1964	-0.1187	0.0779	0.926	0.255	64	69
1965	0.1937	0.1219	1.238	0.421	65	53
1966	-0.4518	0.1899	0.627	0.262	66	105
1967	0.2107	0.0378	1.314	0.254	67	51
1969	-0.6272	0.1245	0.544	0.187	69	127
1970	0.0157	0.0636	1.067	0.266	70	66
1971	0.1898	0.1887	1.192	0.496	71	60
1972	-0.2242	0.0618	0.840	0.207	72	86
1973	-0.0964	0.2109	0.886	0.388	73	82
1974	-0.5797	0.0711	0.586	0.154	74	126
1975	-0.6351	0.0602	0.558	0.135	75	135
1976	-0.2176	0.0250	0.862	0.136	76	88
1977	-0.2907	0.0297	0.799	0.137	77	96
1978	-0.2343	0.0327	0.844	0.152	78	92
1979	0.3207	0.0255	1.476	0.235	79	54
1980	-0.1390	0.0290	0.930	0.158	80	86
1981	-0.0446	0.0281	1.023	0.171	81	79
1982	-0.2267	0.0569	0.840	0.198	82	98
1984	0.0287	0.0985	1.062	0.327	84	79
1985	0.4772	0.0617	1.694	0.416	85	50
1986	0.0078	0.1611	1.008	0.390	86	85
1987	0.2503	0.1069	1.320	0.422	87	66
1988	0.5664	0.1936	1.733	0.730	88	51
1990	0.3314	0.1763	1.382	0.558	90	65
1992	-1.1162	0.0458	0.347	0.074	92	265
1993	-0.8087	0.0779	0.465	0.128	93	200
1994	0.5793	0.0915	1.849	0.549	94	51

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.273

Table 6a. ANOVA results and regression coefficients from a multiplicative model utilized to derive a standardized catch rate series for Redfish in Div. 3O. Only countries who have fished both inside and outside the EEZ were utilized in the analysis. Effort is measured in hours fished (1993 based on preliminary data).

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.808

MULTIPLE R SQUARED..... 0.653

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	6.347E1	6.347E1	
REGRESSION	52	7.47[illegible]E1	1.437E0	7.574
Country/Gear/TC	7	9.617E0	1.374E0	7.242
Month	11	7.537E0	6.852E-1	3.612
Bycatch PCT	4	9.435E0	2.359E0	12.434
Year	30	1.531E1	5.103E-1	2.690
RESIDUALS	209	3.965E1	1.897E-1	
TOTAL	262	1.776E2		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
Country/Gear/TC	20127	INTERCEPT	0.467	0.213	262
Month	-				
Bycatch PCT	95				
Year	59				
	4127	1	-0.181	0.124	19
	4157	2	-0.686	0.111	32
	20114	3	-1.408	0.210	14
	20157	4	-0.139	0.079	58
	34126	5	-0.401	0.378	3
	34127	6	-0.782	0.375	3
	34157	7	-0.556	0.415	2
1	-	8	-0.337	0.149	14
	2	9	-0.404	0.166	11
	3	10	-0.223	0.125	25
	4	11	-0.695	0.125	23
	5	12	-0.145	0.129	22
	6	13	-0.045	0.120	28
	8	14	-0.057	0.109	33
	9	15	-0.112	0.119	26
	10	16	-0.185	0.160	11
	11	17	-0.312	0.155	13
	12	18	-0.241	0.133	22
3	55	19	-0.813	0.146	19
	63	20	-0.496	0.115	31
	75	21	-0.416	0.099	33
	85	22	-0.998	0.087	45
14	90	23	0.540	0.499	1
	92	24	0.699	0.429	2
	93	25	1.013	0.426	2
	64	26	0.484	0.539	1
	65	27	0.245	0.432	2
	69	28	0.526	0.305	4
	70	29	0.241	0.295	6
	71	30	0.625	0.279	7
	72	31	0.247	0.259	8
	73	32	0.545	0.309	4
	74	33	0.647	0.346	3
	75	34	0.553	0.397	2
	76	35	0.671	0.246	11
	77	36	0.699	0.261	8
	78	37	0.333	0.250	10
	79	38	0.689	0.235	15
	80	39	0.803	0.231	16
	81	40	0.873	0.236	13
	82	41	1.083	0.230	16
	83	42	0.743	0.230	17
	84	43	0.608	0.231	16
	85	44	0.559	0.243	12
	86	45	0.543	0.247	12
	87	46	0.593	0.237	14
	88	47	0.600	0.237	14
	89	48	0.389	0.245	12
	90	49	0.189	0.251	9
	91	50	-0.076	0.260	7
	92	51	0.418	0.340	11
	93	52	0.227	0.384	2

Table 6b. Standardized catch rate series for Div. 3O redfish from a multiplicative model utilizing hours fished as a measure of effort. Only countries who fished inside and outside the EEZ were utilized in the analysis.

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1959	0.4672	0.0454	1.715	0.362	59	34
1960	1.0075	0.2212	2.696	1.203	60	22
1962	1.1651	0.1553	3.262	1.240	62	19
1963	1.4799	0.1501	4.481	1.677	63	14
1964	0.9511	0.2603	2.498	1.199	64	26
1965	0.7126	0.1562	2.074	0.790	65	31
1969	0.9932	0.0611	2.880	0.703	69	24
1970	0.7082	0.0543	2.173	0.501	70	32
1971	1.0926	0.0490	3.200	0.702	71	22
1972	0.7141	0.0345	2.208	0.407	72	33
1973	1.0119	0.0585	2.938	0.702	73	25
1974	1.1137	0.0902	3.202	0.942	74	23
1975	1.0200	0.1187	2.874	0.964	75	26
1976	1.3379	0.0295	4.130	0.706	76	18
1977	1.1666	0.0364	3.468	0.657	77	22
1978	0.7997	0.0303	2.410	0.418	78	32
1979	1.1564	0.0263	3.450	0.557	79	23
1980	1.2703	0.0218	3.875	0.571	80	21
1981	1.3397	0.0243	4.149	0.644	81	20
1982	1.5505	0.0184	5.138	0.695	82	16
1983	1.2099	0.0213	3.649	0.530	83	23
1984	1.0753	0.0205	3.191	0.454	84	26
1985	1.0261	0.0273	3.027	0.498	85	28
1986	1.0099	0.0279	2.978	0.495	86	29
1987	1.0605	0.0230	3.140	0.475	87	28
1988	1.0670	0.0214	3.163	0.462	88	28
1989	0.8558	0.0259	2.555	0.409	89	35
1990	0.6559	0.0290	2.089	0.354	90	43
1991	0.3915	0.0334	1.600	0.291	91	57
1992	0.8853	0.0798	2.561	0.711	92	36
1993	0.6946	0.1099	2.085	0.674	93	45

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.232

Table 7a. ANOVA results and regression coefficients from a multiplicative model utilized to derive a standardized catch rate series for Redfish in Div. 3O. Only countries who have fished outside the EEZ were utilized in the analysis. Effort is measured in hours fished (1993 based on preliminary data).

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.712

MULTIPLE R SQUARED..... 0.507

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	1.588E1	1.588E1	
REGRESSION	40	2.049E1	5.121E-1	2.054
Country*Gear*TC	7	1.576E0	2.252E-1	0.903
Month	11	3.150E0	2.863E-1	1.149
Bycatch PCT	4	5.344E0	1.336E0	5.359
Year	18	5.057E0	2.810E-1	1.127
RESIDUALS	80	1.994E1	2.493E-1	
TOTAL	121	5.631E1		

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
Country*Gear*TC	14127	INTERCEPT	1.838	0.851	12
Month	8				
Bycatch PCT	95				
Year	85				
*	14124	1	0.028	0.250	8
	14125	2	-0.191	0.281	5
	14126	3	0.210	0.226	18
	16127	4	-0.564	0.357	6
	17128	5	-0.130	0.300	8
	25126	6	0.050	0.222	17
	25127	7	0.228	0.180	29
(2)	1	8	-0.351	0.365	3
	2	9	-0.374	0.291	7
	3	10	-0.096	0.238	11
	4	11	-0.340	0.356	4
	5	12	0.028	0.248	7
	6	13	-0.112	0.280	5
	7	14	-0.176	0.199	13
	9	15	0.085	0.193	16
	10	16	0.052	0.189	15
	11	17	-0.359	0.209	12
	12	18	-0.445	0.219	10
3	55	19	-0.474	0.350	2
	65	20	-0.383	0.585	1
	75	21	-0.907	0.251	5
	85	22	-0.505	0.141	27
(4)	69	23	-1.215	0.631	2
	70	24	-0.088	0.844	1
	71	25	-0.680	0.604	6
	72	26	-1.105	0.636	3
	73	27	-0.666	0.684	4
	74	28	-1.529	0.730	2
	79	29	-1.541	0.929	1
	82	30	-1.302	0.673	6
	84	31	-0.829	0.680	6
	85	32	-0.915	0.679	6
	86	33	-1.076	0.696	5
	87	34	-0.976	0.658	17
	88	35	-1.011	0.666	15
	89	36	-1.187	0.664	14
	90	37	-1.088	0.657	14
	91	38	-1.153	0.731	3
	92	39	-1.289	0.675	14
	93	40	-1.819	0.836	1

Table 7b. Standardized catch rate series for Div. 3O redfish from a multiplicative model utilizing hours fished as a measure of effort. Only countries who have fished outside the EEZ were utilized in the analysis.

PREDICTED CATCH RATE

	LN TRANSFORM		RETRANSFORMED			
YEAR	MEAN	S.E.	MEAN	S.E.	CATCH	EFFORT
1966	1.6859	0.3979	5.006	2.883	66	13
1969	0.4695	0.2636	1.588	0.768	69	43
1970	1.5981	0.3280	4.750	2.525	70	15
1971	1.0058	0.0768	2.984	0.816	71	24
1972	0.5808	0.1181	1.910	0.641	72	38
1973	1.0202	0.0788	3.024	0.837	73	24
1974	0.1573	0.1345	1.240	0.443	74	60
1979	0.1452	0.4611	1.039	0.634	79	76
1982	0.3735	0.0735	1.588	0.425	82	52
1984	0.8571	0.0822	2.564	0.725	84	33
1985	0.7713	0.0706	2.367	0.622	85	36
1986	0.6102	0.0828	2.003	0.568	86	43
1987	0.7096	0.0466	2.253	0.484	87	39
1988	0.6752	0.0516	2.171	0.490	88	41
1989	0.4986	0.0526	1.819	0.414	89	49
1990	0.5982	0.0501	2.012	0.447	90	45
1991	0.5325	0.1405	1.800	0.655	91	51
1992	0.3971	0.0683	1.630	0.421	92	56
1993	-0.1330	0.3261	0.842	0.447	93	110

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.347

Table 8. Mean weight (kg) of redfish caught per standard tow in Division 3O during Canadian research surveys 1991-1995. ("-" indicates strata not sampled)

STRATUM	Depth Range (m)	Area* sq. n. mi	1991 Spring	1991 Autumn	1992 Spring	1992 Autumn	1993 Spring	1993 Summer	1993 Autumn	1994 Spring	1994 Autumn	1995 Spring
329	093-183	1721	0.08	0.00	0.00	0.00	0.00	0.00	0.00	4.70	0.00	0.07
332	093-183	1047	0.13	0.00	0.24	14.12	0.00	0.00	0.97	0.00	14.90	129.68
333	185-274	151(147)	84.18	16.75	303.73	125.93	1195.53	0.00	29.15	3859.26	216.43	83.51
334	275-366	92(96)	95.99	1168.88	32.75	420.61	234.80	0.00	348.03	152.82	175.26	30.98
335	275-366	58	2.77	393.74	59.00	755.40	134.54	3845.49	301.02	1260.90	806.07	184.85
336	185-274	121	6.68	6.00	60.30	284.58	557.00	134.57	291.29	699.95	204.57	5194.17
337	093-183	948	4.44	37.95	1.77	38.30	0.95	0.00	7.77	0.00	4.30	198.92
339	093-183	585	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
354	093-183	474	0.00	0.00	0.00	214.50	221.80	149.61	0.00	0.00	0.00	0.00
355	185-274	103	0.64	70.30	0.36	193.90	851.25	55.10	39.13	392.48	392.40	99.88
356	275-366	61	9.90	40.15	104.43	673.55	494.82	2287.02	47.70	120.13	231.30	333.29
717	367-549	93(166)	597.91	---	87.75	---	110.03	0.00	1539.17	489.23	400.90	113.34
718	550-731	111(134)	49.39	---	8.30	---	101.90	0.00	203.82	208.85	---	7.65
719	367-549	76	27.68	318.02	11.85	---	192.85	1815.75	993.30	887.30	555.71	79.65
720	550-731	105	12.44	---	68.18	---	10.18	35.87	57.63	19.12	146.35	17.10
721	367-549	76	21.65	55.13	49.03	---	143.25	1247.77	106.00	25.40	18.95	1114.63
722	550-731	93	149.13	8.80	13.37	---	39.94	56.22	202.57	159.32	26.90	6.20
Upper			120.04	274.18	79.25	163.42	243.40	1008.21	127.90	779.24	111.33	284.29
Mean			18.20	37.19	15.22	65.24	93.50	597.47	64.02	164.87	51.46	186.74
Lower			-83.63	199.80	-48.81	-32.93	-56.38	126.72	0.13	-449.50	-8.42	89.19
TOTAL BIOMASS (metric tons)			8082	15649	6759	26256	41518	52338	28423	74391	22700	84261

*NOTE: In brackets are revised areas based on a redrawn stratification scheme implemented in 1994.

Table 9. ANOVA results and estimated slope (β) for catch curve analysis of catch at age data for Div. 3O available from 1987-1990 (see text). The slope of the regression of the descending limb of the curve is an estimate of total mortality (Z).

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* * * * * * Analysis of Variance -- design 1 * * * * * *

Tests of Significance for LN_N_EFF using UNIQUE sums of squares
Source of Variation          SS      DF        MS         F  Sig of F

WITHIN+RESIDUAL            9.28      47       .20
REGRESSION                 5.27       1      5.27     26.71      .000
SER_YC                     7.46      19       .39      1.99      .029


(Model)                  234.81      20     11.74     59.48      .000
(Total)                  244.08      67      3.64

R-Squared =           .962
Adjusted R-Squared =  .946

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Regression analysis for WITHIN+RESIDUAL error term
--- Individual Univariate .9500 confidence intervals
Dependent variable .. LN_N_EFF

COVARIATE            B        Beta   Std. Err.     t-Value   Sig. of t

AGE            -.26513     -.68557        .051      -5.168        .000

COVARIATE   Lower -95% CL- Upper

AGE              -.368       -.162
```

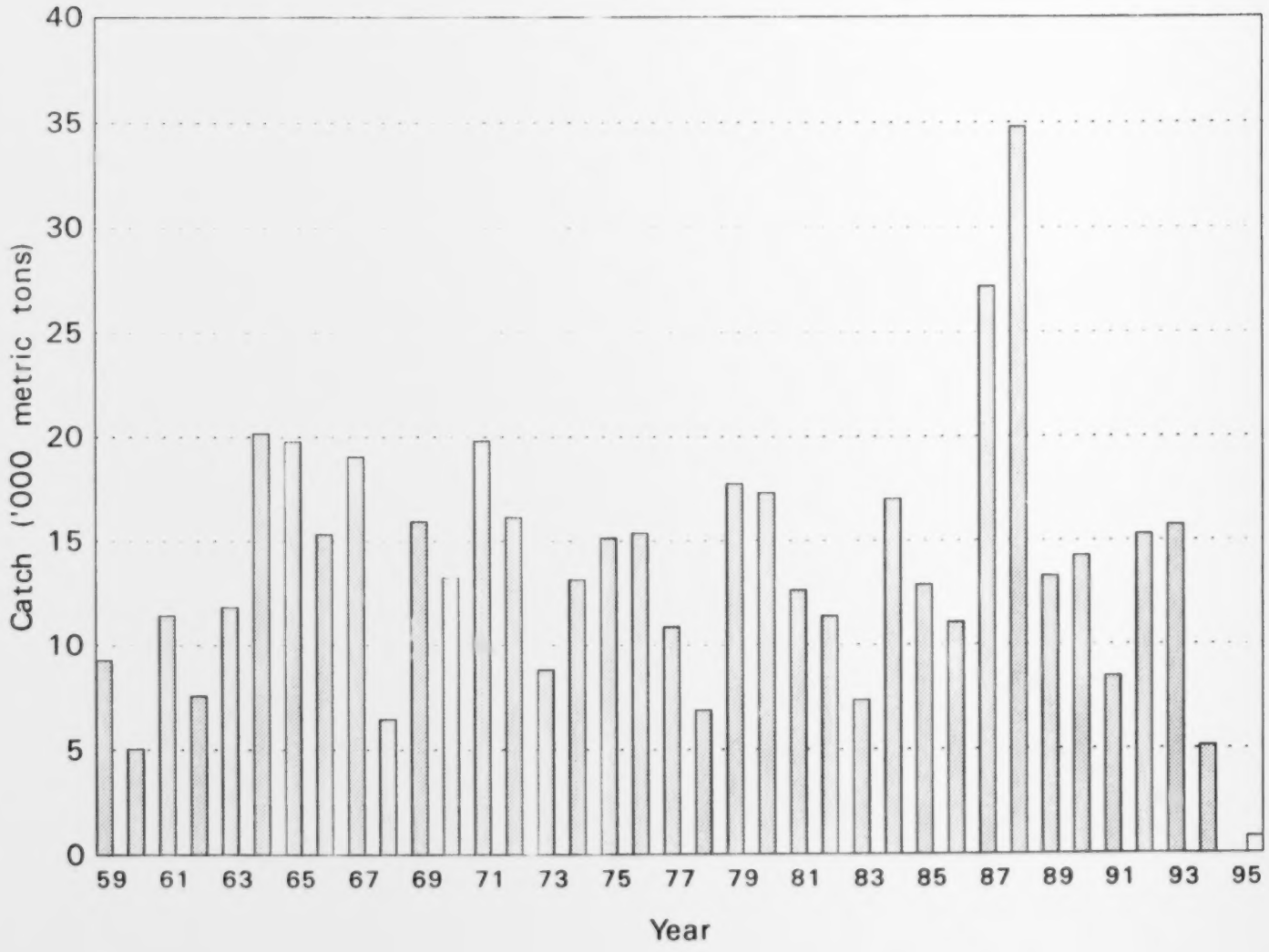

Fig. 1. Nominal catch of redfish in Div. 3O from 1959-1995. (1995 preliminary to Sept. 20)

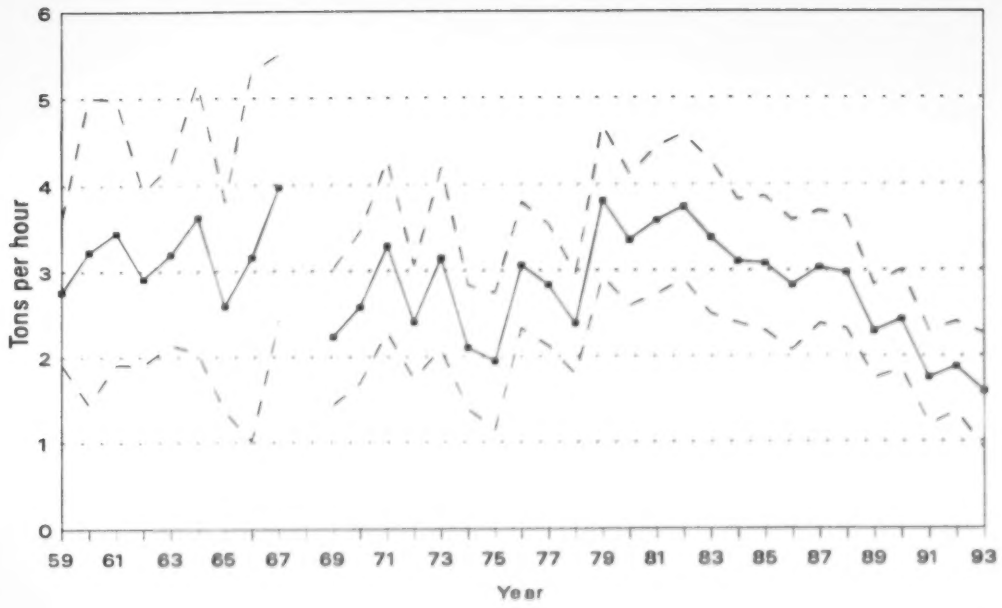

Fig. 2a. Standardized CPUE with approximate 95% confidence intervals for redfish in Div. 3O utilizing all countries. Effort based on hours fished.

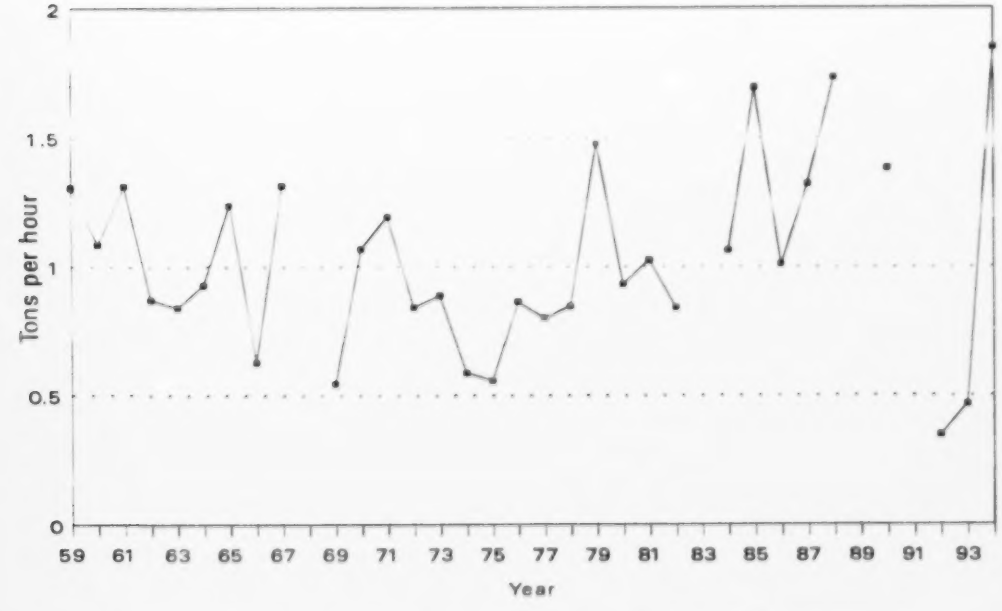

Fig. 2b. Standardized CPUE for redfish Div. 3O for Canada fishing inside the EEZ based on hours fished.

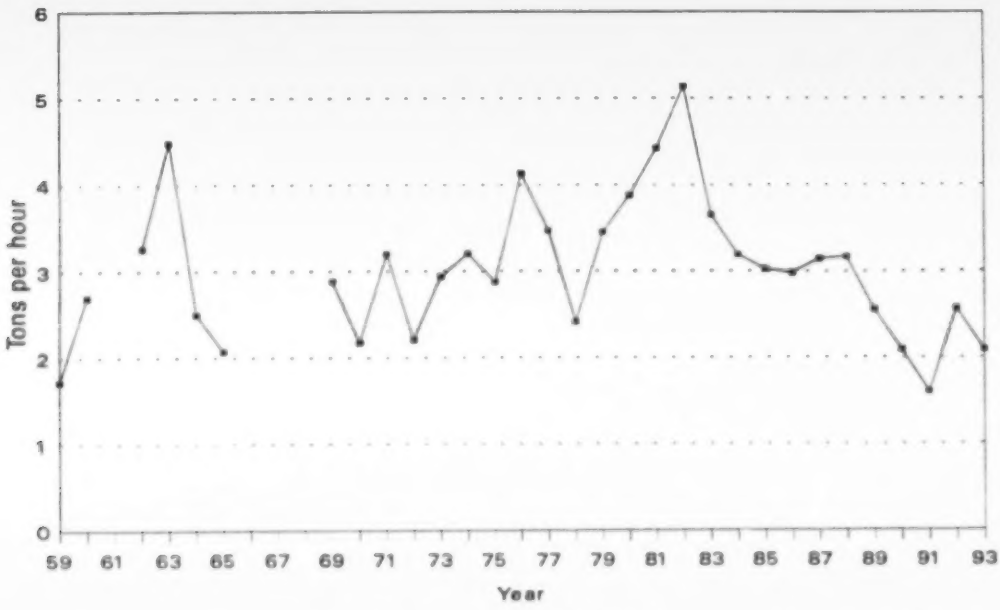

Fig. 2c. Standardized CPUE for redfish Div. 3O for countries that fished inside and outside the EEZ (Russia and Cuba) based on hours fished.

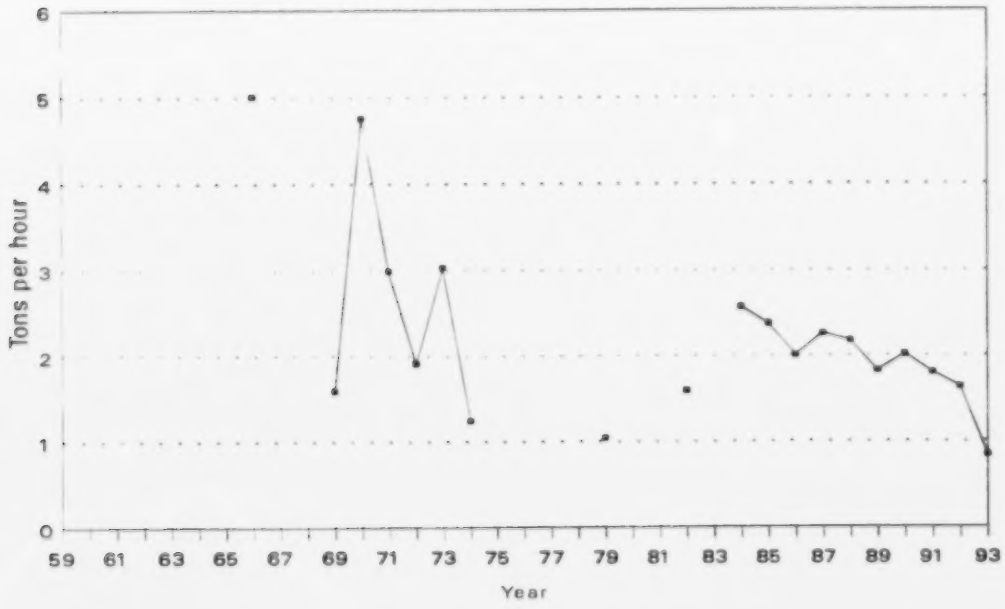

Fig. 2d. Standardized CPUE for redfish Div. 3O for countries that fished outside the EEZ based on hours fished.

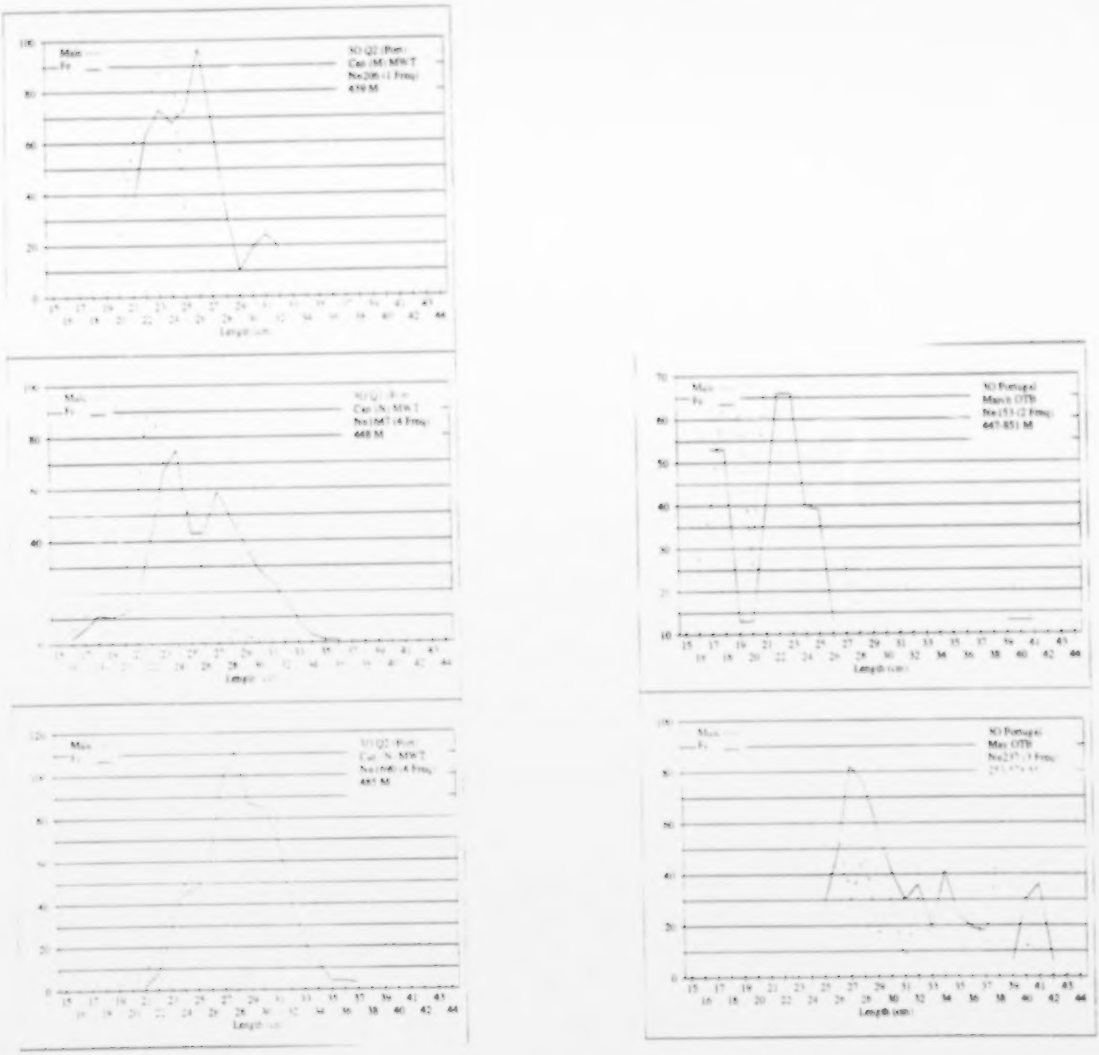

Fig. 3. Length distributions (number per thousand) sampled from the commercial fishery in Div. 3O by Canadian port samplers and Portuguese observers aboard Portuguese vessels in 1994.

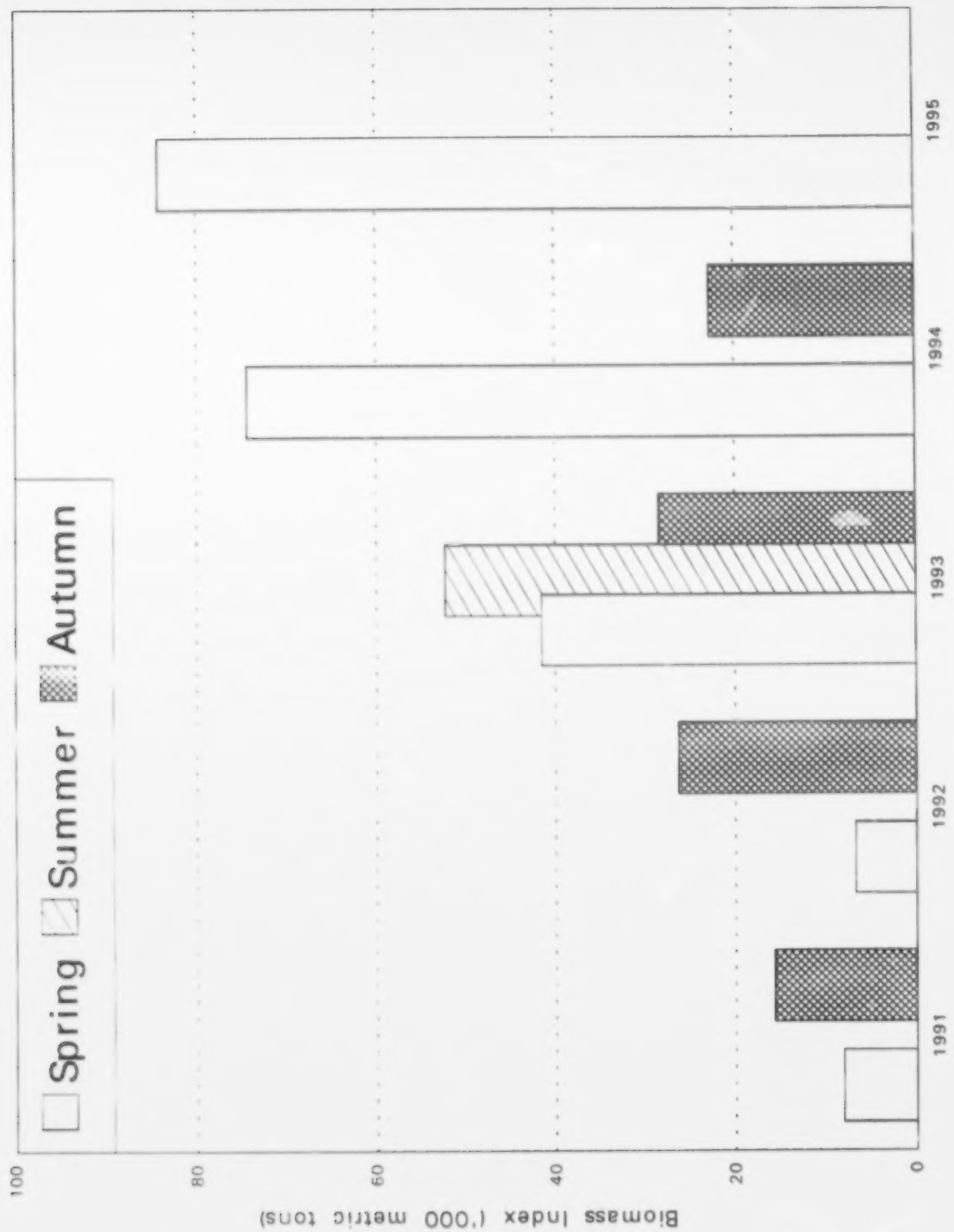

Fig. 4. Research survey biomass index for Div. 3O redfish from 1991-1995.

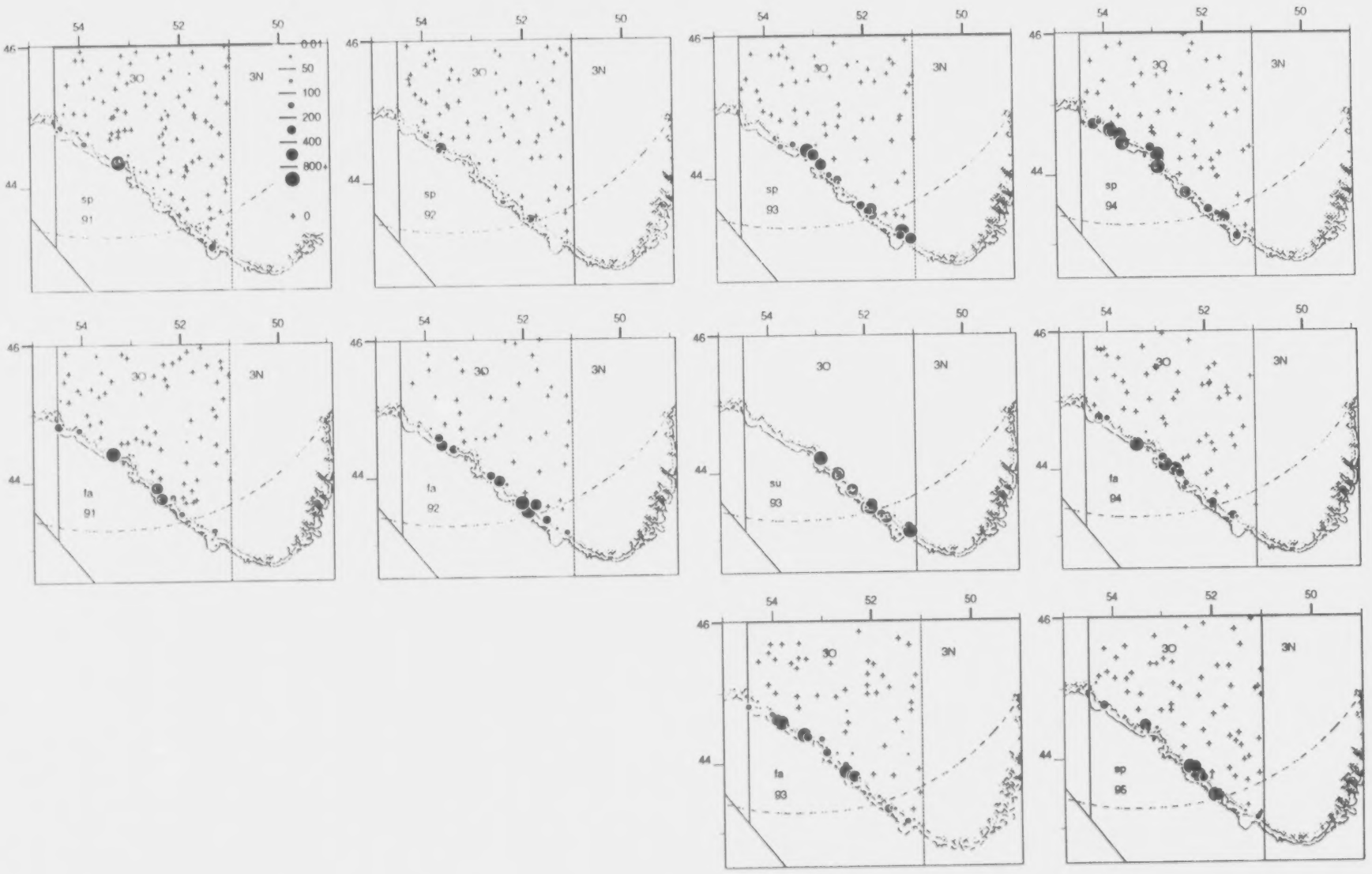

Figure 5. Distribution of redfish catches from Canadian research vessel surveys during 1991-95 in NAFO Division 3O

Plots are of the catch (kg) per standard tow (30 min X 3.5 knots with Engels 145 lined otter trawl).

sp=spring su=summer fa=fall

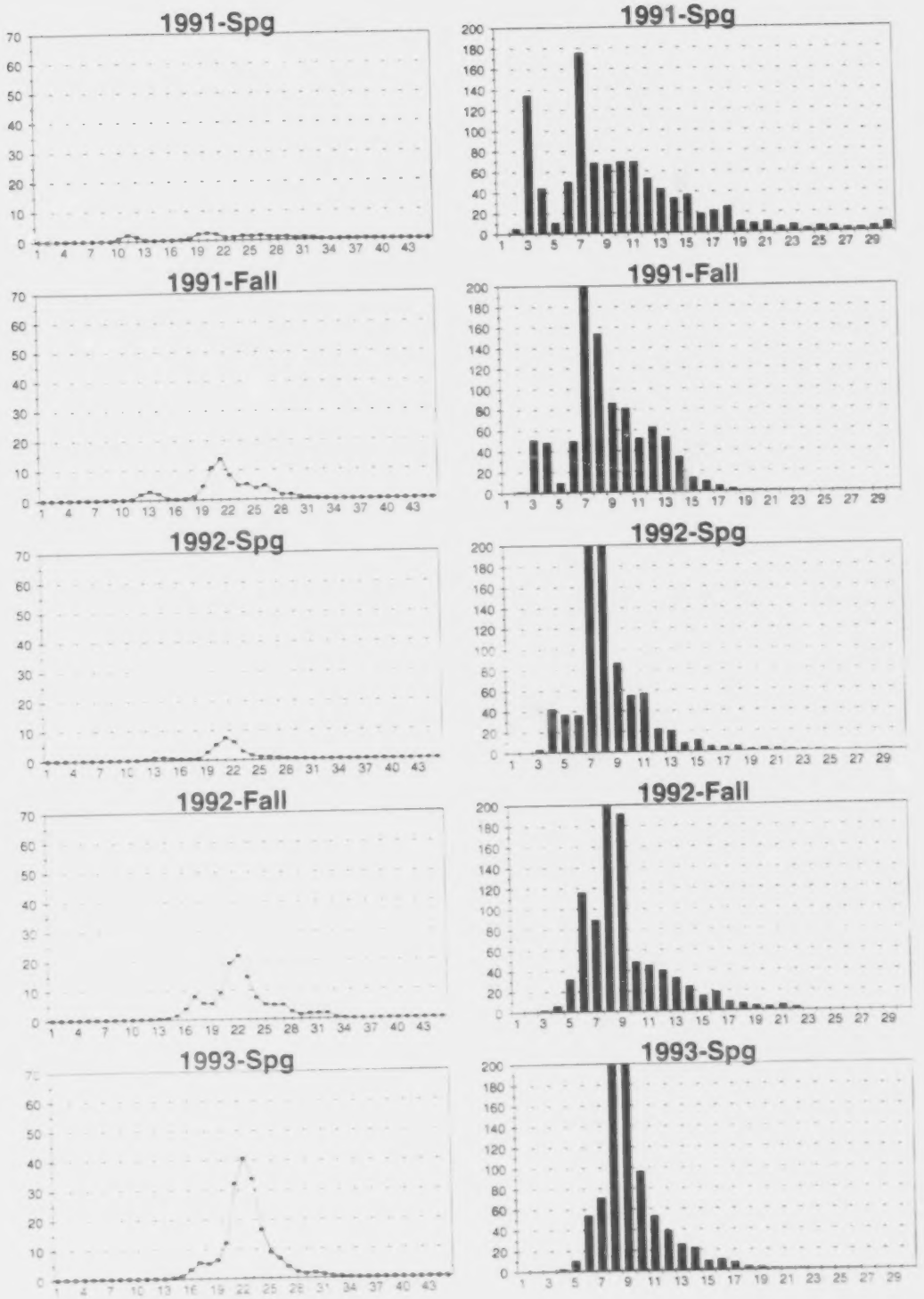

Fig. 6. Length frequencies and corresponding age distribution from stratified-random research surveys to Div. 3O from 1991-1995. Plotted above are mean number per standard tow (left) and corresponding number per thousand age distribution (right). X-axis is forklength in centimetres for left plot, and age in years for right plot.

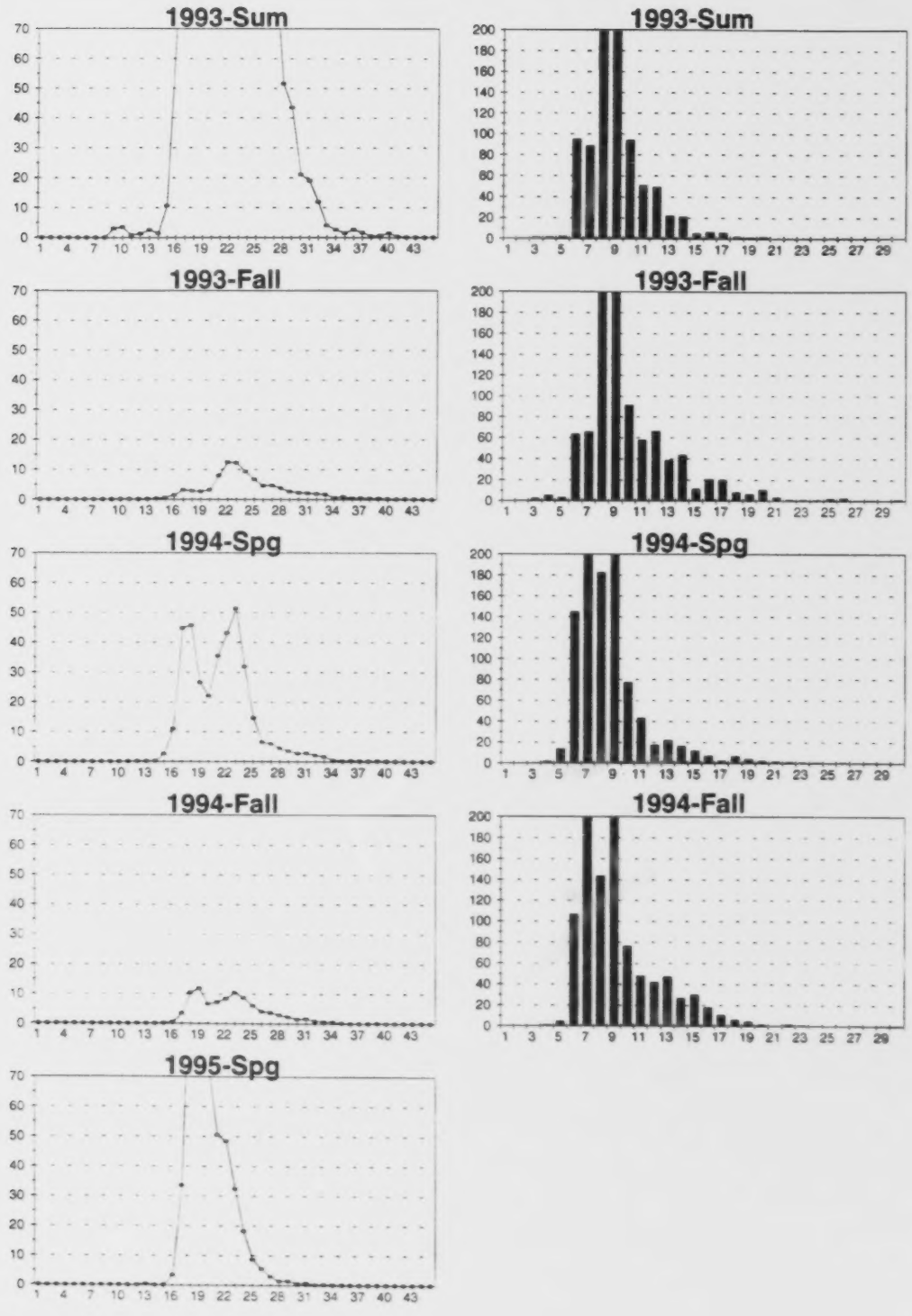

Fig. 6. (continued)